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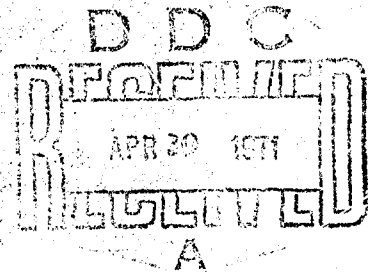
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## MUZZLE FLASH MEASUREMENTS ON LARGE GUNS

Edward M. Lerner



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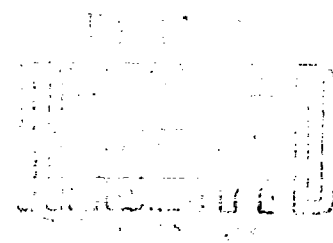
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August 1968

MUZZLE FLASH MEASUREMENTS  
ON LARGE GUNS

by

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#### FOREWORD

In the testing of propellant at the U. S. Naval Weapons Laboratory, relative muzzle flash intensities on individual rounds of large guns were recorded by human observers. Because of the human eye response variance from individual to individual and for differing lighting conditions, it has been impossible to compare flash intensities with a reasonable degree of confidence. In order to accurately compare propellant flash measured under varying conditions, a calibrated photodiode detection system simulating human eye response was developed.

This work was performed in the Standardization and Technical Services Branch of the Instrument Development Division of the Engineering and Evaluation Department.

Released by:



D. W. STONER  
Director, Engineering and  
Evaluation Department

#### ABSTRACT

A photodiode, modified to give a human eye response, was calibrated against a standard of spectral irradiance. The calibration procedure is explained in detail. This photodiode can then be used to measure, in absolute units, the muzzle flash intensities of large guns. The results of previous tests, regardless of ambient lighting conditions, can be compared.

A computer program, graphs and schematics are included.

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## INTRODUCTION

The intent of this project was to develop a calibrated system to simulate the human eye in spectral response (Figure 1) in the measurement of flash. A photodiode (EG & G SGD-444) in conjunction with a wide band-pass optical filter (IL/WB-510) was chosen. This combination closely matches the human eye response and eliminates response to the infrared radiation from the flash. The system measures in absolute units just what the human eye sees. In addition, the photodiode-filter combination offers many advantages over the human eye. These include a known and unvarying response curve, good linearity, and calibration against a standard of spectral irradiance.

## SYSTEM DESCRIPTION

The photodiode and filter are mounted in a detector housing which is located on the bridge at Main Range and aimed just ahead of the muzzle of the gun being fired. If the flash is expected to be unusually intense, a calibrated neutral density filter, or an optical attenuator, is placed in front of the filter. The output of the diode is fed to a galvanometer in a CEC 5-133 recorder. The output of the detector is amplified and matched to the galvanometer through a Honeywell amplifier. The system schematic is shown in Figure 2.

Prior to the test, calibration steps are placed on the oscillograph record by a flash calibration panel.

## CALIBRATION

### 1. Procedure

Calibration of the gun flash detector is based on a standard of spectral irradiance. The standard lamp, which is traceable to the National Bureau of Standards, is factory calibrated by the Eppley Laboratory, Inc. and checked by NWL.

Figure 4 shows the optical filter/detector spectral response curve. This plot is obtained by first measuring the spectral variation of irradiance by use of a detector of known spectral responsivity at a known position, the plane of calibration (See Figure 3). With this information the spectral responsivity of the combination can be determined.

Multiplication of the lamp output curve by the normalized combination curve yields the spectral responsivity curve. Actual values are shown in Table 1. It is this curve which must be integrated to obtain the combination power responsivity ( $\text{mv.watt}^{-1}$ ). A computer program has been written that permits the evaluation of this parameter. The program is included in Appendix A.



Calibrated neutral density filters (optical attenuators) are placed between the standard lamp and the detector to check linearity (Figure 5). Since the standard lamp obeys the inverse square law for distances greater than 43 cm, linearity can also be checked by changing the distance between lamp and detector. For instance, doubling the distance will cut the irradiance by 75%, while tripling will produce an 89% reduction. This method, however, is difficult to implement and is used only as a check of the neutral density filters.

### 2. Calibration Panel:

From the previously described procedure, the detector responsivity was determined. The calibration panel (Figure 6) places known steps of voltages on the oscillograph record (See Figure 7).

### 3. Calibration Uncertainty:

A survey of the available optical instruments now on the market will give ample evidence of the poor accuracy to be expected in radiometry today compared to the accuracies obtained in other fields of measurement; the calibration accuracy of the standard of spectral irradiance is  $\pm 5\%$ . Although this uncertainty drops to  $\pm 2\%$  in the infrared region, it is highest in the visible spectrum.

The actual response curve obtained is shown in Figure 4. The error produced by the perturbation at 800 nm was calculated to be less than  $\pm 3\%$ . This is well within the uncertainty due to the standard of spectral irradiance.

The computer program was used to eliminate error due to integrating the calibration curve by mechanical methods. A sample problem used for a test showed a computer error of less than  $\pm 0.6\%$ .

### REDUCTION OF DATA

From the calibration steps on the oscillograph record the values of flash irradiances can be determined from the trace deflection by the following relation.

$$E = D \cdot \Delta d \cdot R_p^{-1}$$

where  $E$  = irradiance in  $\text{uw} \cdot \text{cm}^{-2}$

$D$  = deflection responsivity in  $\text{mv} \cdot \text{mm}^{-1}$

$\Delta d$  = deflection above ambient in mm

$R_p$  = detector responsivity  $\text{mv} \cdot \text{cm}^2 \cdot \text{uw}^{-1}$

The deflection  $\Delta d$  is the peak deflection due to flash minus the

deflection due to ambient light as can be seen in Figure 8.

The value reported is the peak radiant flux density (E) incident on the detector face corrected to a 100 foot reference distance through use of the inverse square law.

#### CONCLUSION

Using the calibrated photodiode system, flash intensities can be measured in absolute units. This enables the intensities of individual rounds in a given test to be accurately compared. The results of previous tests, regardless of ambient lighting conditions, can also be compared.

#### RECOMMENDATIONS

Data acquisition and reduction can be done more quickly through use of peak reading meters rather than paper recorders. If the requirement for flash measurements becomes extensive, however, the system will have to be converted to a form suitable to automatic data processing without manual record reading.

APPENDIX A

COMPUTER PROGRAM LISTING

```

H      TYPE,COMPILEGO,FORTRAN,PM
T      SUBTYPE,FORTRAN,EMAP,PUNCH
1  FORMAT (10, 5X, F6.3)
2  FORMAT (10,2X,F10.3, 5X, F7.3)
3  FORMAT (8F10.3)
4  FORMAT(9H FOR THE ,10,26H SUBINTERVAL, THE AREA IS ,F14.4)
5  FORMAT(35H THE VALUE OF THE INTEGRAL FOR THE ,10,16H SET OF DATA 1
   IS ,F14.4)
   DIMENSION X(501), Y(501), XNCRMT(3001), YNCRMT(3001)
   INTEGER SUBIN
   REAL INTGRL
   READ 1, NOSETS, H
   DO 11 I = 1, NOSETS
     INTGRL = 0.0
     READ 2, ICARD, FIRSTX, D
     READ 3, (Y(J), J = 1, ICARD)
     DO 6 J = 1, ICARD
7   X(J) = FIRSTX + FLOAT(J - 1) * D
     NXNCRT = 2.0 * D / H + 1.0
     NSUBIN = ((ICARD - 3) / 2 + 1)
     DO 10 K = 1, NSUBIN
       XL11 = X(2 * K - 1)
       XL12 = X(2 * K)
       XL13 = X(2 * K + 1)
       YL11 = Y(2 * K - 1)
       YL12 = Y(2 * K)
       YL13 = Y(2 * K + 1)
       DO 7 L = 1, NXNCRT
         XNCRMT(L) = XL11 + FLOAT(L - 1) * H
7       YNCRMT(L) = ((XNCRMT(L) - XL12) * (XNCRMT(L) - XL13) * YL11) / ((
         1XL11 - XL12) * (XL11 - XL13)) + ((XNCRMT(L) - XL11) * (XNCRMT(L) -
         2XL13) * YL12) / ((XL12 - XL11) * (XL12 - XL13)) + ((XNCRMT(L) -
         3XL11) * (XNCRMT(L) - XL12) * YL13) / ((XL13 - XL11) * (XL13 - XL12
         4))
       Y0 = YNCRMT(1)
       YN = YNCRMT(NXNCRT)
       YEVEN = 0.0
       YODD = 0.0
       LASTEX = NXNCRT - 2
       LASTOX = NXNCRT - 1
       DO 8 M1 = 3, LASTEX, 2
8       YEVEN = YEVEN + YNCRMT(M1)
       DO 9 M2 = 2, LASTOX, 2
9       YODD = YODD + YNCRMT(M2)
       AXL1L3 = H / 3.0 * (Y0 + 4.0 * YODD + 2.0 * YEVEN + YN)
       PRINT 4, K, AXL1L3
10    INTGRL = INTGRL + AXL1L3
       PRINT 5, I, INTGRL
       RETURN
     END
   END
989

```

APPENDIX B

FIGURES AND TABLES

TABLE 1  
"Spectral Power Distribution"

nm	PD	nm	PD	nm	PD
400	0.016	535	7.59	670	2.29
405	0.030	540	8.27	675	1.82
410	0.048	545	9.10	680	1.44
415	0.067	550	9.79	685	1.36
420	0.085	555	10.6	690	1.05
425	0.112	560	11.2	695	1.07
430	0.148	565	11.8	700	0.873
435	0.231	570	12.4	705	0.993
440	0.257	575	12.8	710	1.00
445	0.318	580	13.0	715	1.01
450	0.420	585	13.0	720	0.793
455	0.534	590	12.9	725	0.919
460	0.692	595	12.7	730	0.696
465	0.802	600	12.0	735	0.817
470	1.08	605	11.6	740	0.823
475	1.25	610	10.8	745	0.709
480	1.51	615	9.94	750	0.714
485	1.80	620	8.91	755	0.599
490	2.18	625	8.13	760	0.602
495	2.52	630	7.34	765	0.729
500	2.98	635	6.35	770	0.486
505	3.47	640	5.52	775	0.488
510	4.04	645	4.87	780	0.739
515	4.63	650	4.02	785	0.738
520	5.21	655	3.63	790	0.742
525	5.97	660	2.86	795	0.622
530	6.64	665	2.61	800	0.622

Where nm = wavelength

PD = power density in ( $\text{uw.cm}^{-2}$ )

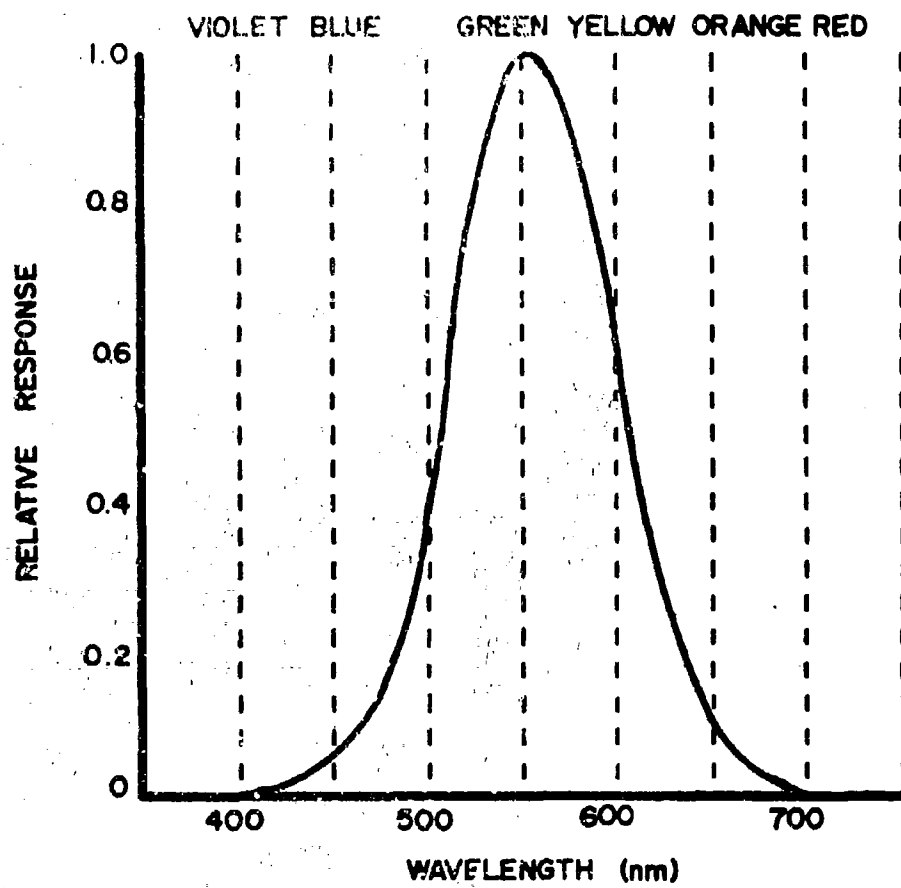


FIGURE 1

NORMALIZED HUMAN EYE RESPONSE

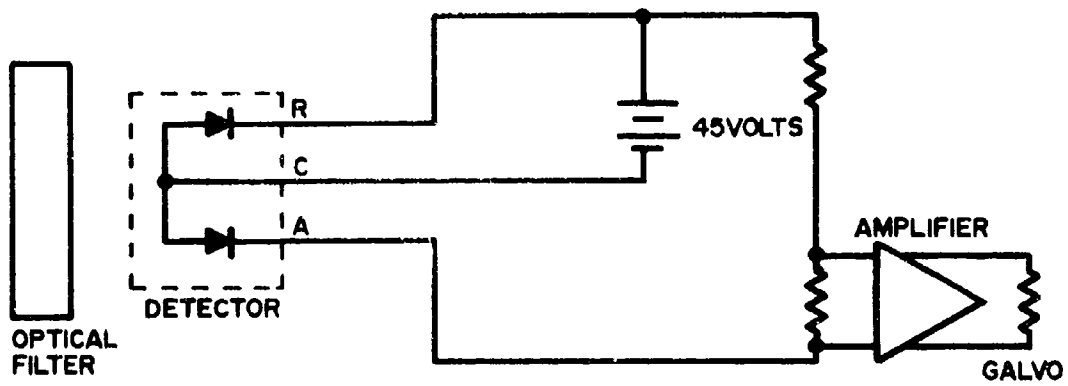


FIGURE 2

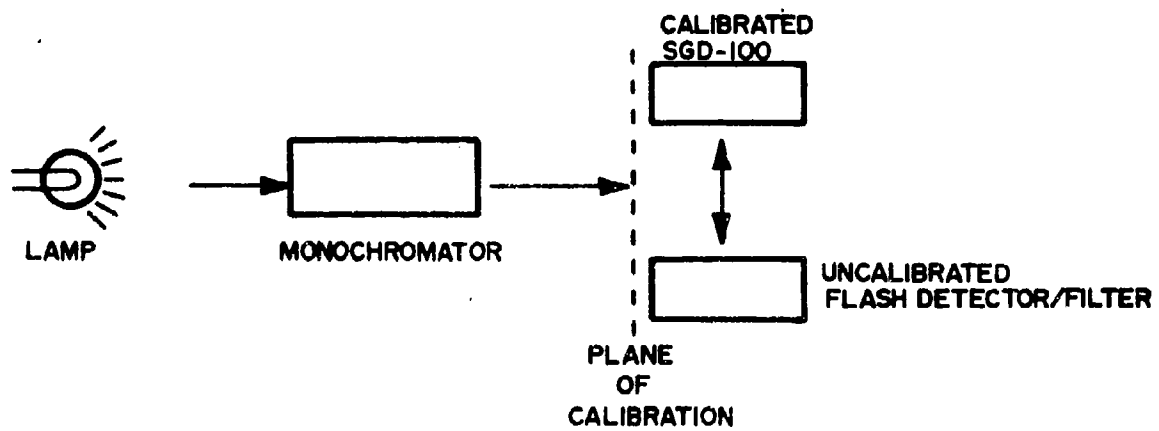


FIGURE 3



ACTUAL RESPONSE CURVE  
OF DETECTOR

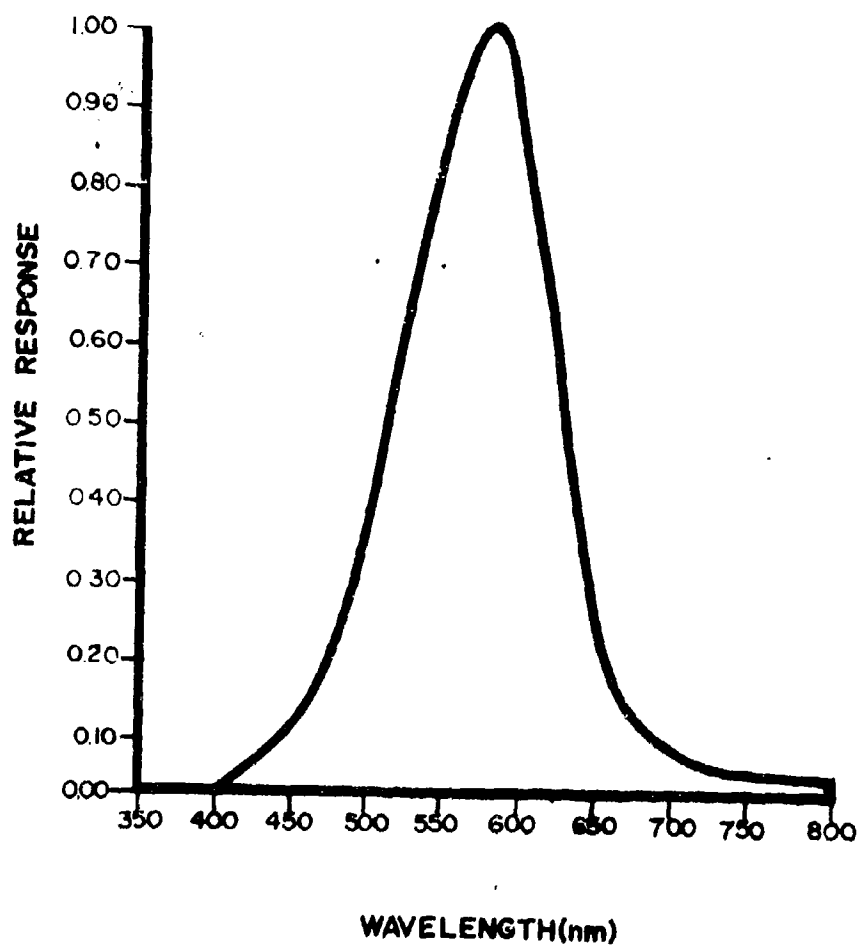


FIGURE 4

# CALIBRATION PROCEDURE

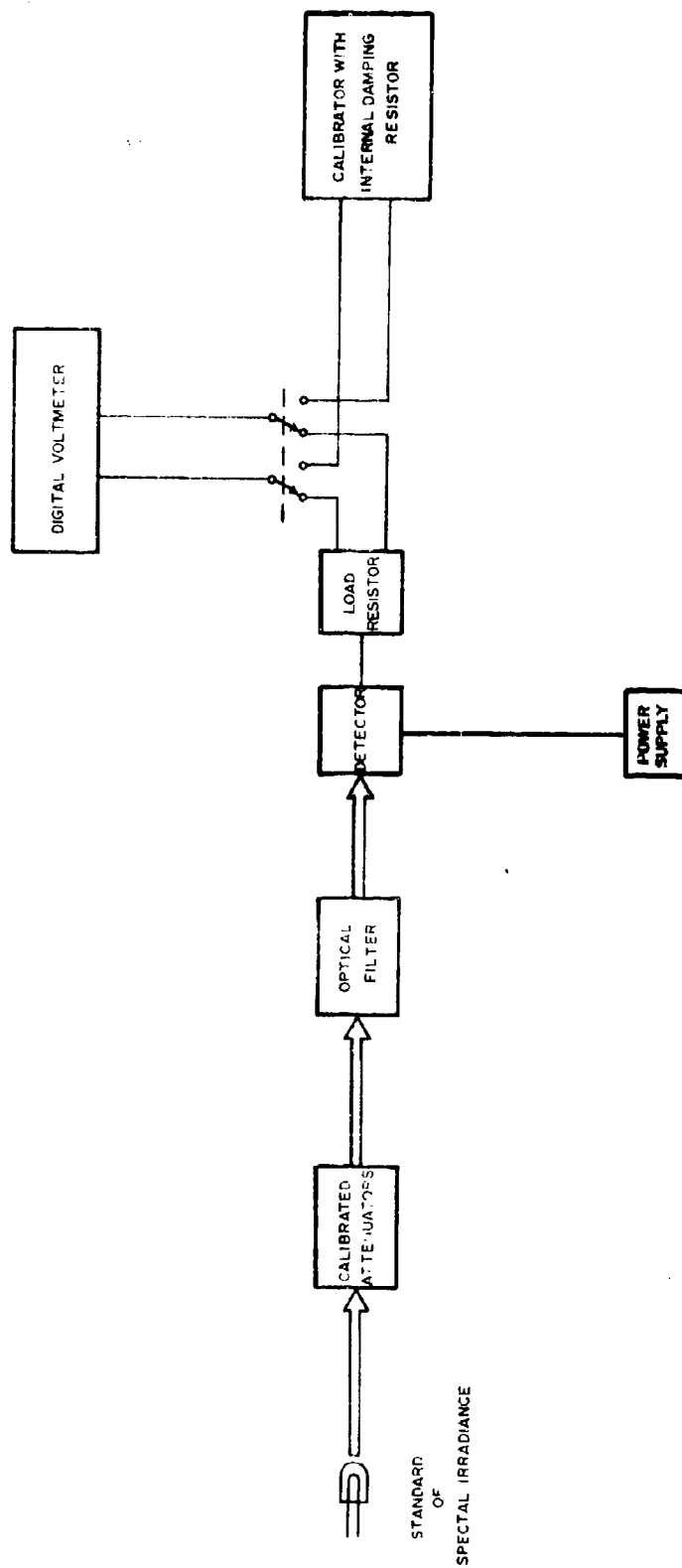
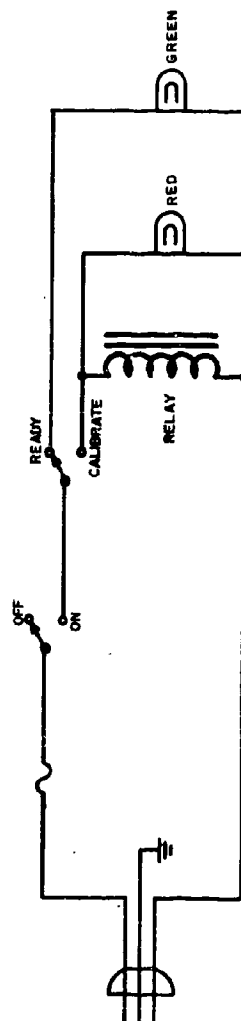


FIGURE 5

The diagram shows a circuit for a relay. A 22 1/2 VOLT battery is connected to a series of resistors R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, and R<sub>4</sub>. The output of this series is connected to a relay. The relay has a switch that can be moved between two positions. One position connects the relay to a resistor R<sub>L</sub>, which is then connected to terminal J2. The other position connects the relay to a common terminal. Terminal J1 is connected to a resistor R<sub>D</sub>, which is then connected to terminal 2. Terminal 1 is connected to a common terminal. The circuit is labeled 'FROM DETECTOR' and 'TO GALVANOMETER'.



**FIGURE 6**

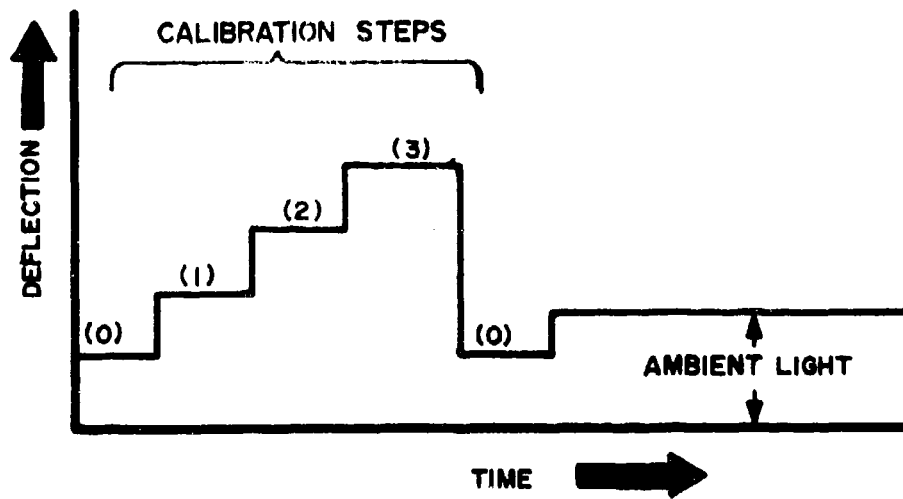


FIGURE 7

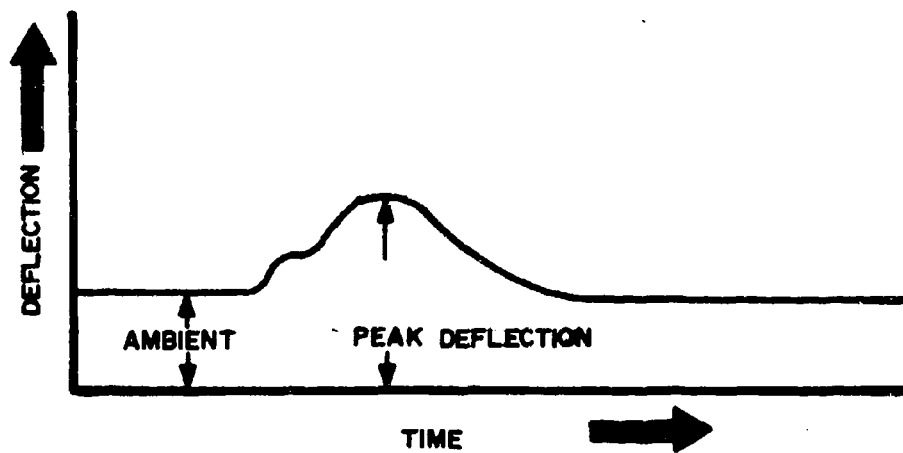


FIGURE 8

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